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RISK ASSESSMENT USING SEISMIC RISK MANAGEMENT AND RESPONSE ANALYSIS OF BASE ISOLATION STRUCTURE

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***ABSTRACT*:** For structures that receive a large earthquake it is required to apply a good technique which suppresses a danger to the minimum irrespective of existing and establishment. A technique of seismic risk management dealt with the quantitative amount of information is to obtain the anticipative amount of the earthquake damages during access period,and is the support tool to select the higher expense efficiency step to reduce an earthquake damage. In this study,the method of seismic risk management is searched for using the earthquake proof reliability assessment technique. A seismic lose function is calculated from the earthquake damage factors that are modeled by using fragility curves and event trees. The seismic hazard curve is obtained by Nankai offshore scenario earthquake. The third floor or the eighth floor steel structures on a hard or soft ground in Kochi Prefecture are taken up as SRM(Seismic Risk Management Method) study cases. Using structures from as three kinds of seismic code,costs of both initial construction and life cycle are calculated. As the results,the seismic risk reduces to half by ground conditions. Though initial investment becomes high so that earthquake resistant construction goes up,the life cycle costs and the seismic risk become small. The seismic risk of the base isolation structure is set to zero,and excels as the earthquake resistant construction. Then,the eighth floor steel structure with the base isolation system is applied to obtain time history responses in comparison of those by the different input wave motions. The base isolation building is able to reduce a strong motion because of the long time period shake,and is effective to the short period large earthquake motion.

***KEYWORDS*:** seismic risk management,response of the steel structure with base isolation system

1. INTRODUCTION

After the 1995 Hanshin Great Earthquake Disaster,the collapsed parts of structure are admitted because of the large,rase earthquake. Not only proper methods for hardware infrastructure to increase the stiffness,but also those for software such as the risk conception are acceptable. For structures that receive a large earthquake it is required to apply the good technique which suppresses the danger to the minimum irrespective of existing and establishment. A technique of seismic risk management dealt with the quantitative amount of information is to obtain the anticipative amount of the earthquake damages during access period,and is the support software tool to select the higher expense efficiency step to reduce the earthquake damage. As a quantitative evaluation method,risk management method based on the probabilistic theory is proposed by an insurance field smashed owing to the 1927 world panic and expands to an atomic field in 1950's period. The Seismic Risk Management(SRM) method for construction field is proposed by Shinozuka Research Group. The risk concepts of a retention,a transfer,or a evasion are inquired to the unsettled part of a risk reduction. Estimated damage costs from database can be obtained as the seismic risk.

In this study,the method of seismic risk management is searched for using the earthquake proof reliability assessment technique. A seismic lose function is calculated from the earthquake damage factors that are modeled by using fragility curves and event trees. A seismic risk curve can be obtained by combining the seismic lose function with the seismic hazard curve. A seismic hazard curve is obtained by Nankai offshore scenario earthquake. The third floor or the eighth floor steel structures on a hard or a soft ground in Kochi Prefecture are taken up as SRM(Seismic Risk Management Method) study cases. Using structures from as three kinds,earthquake resistant A(present standard),earthquake resistant B(increase of 20% about power proof and rigidity) and base isolation system,costs of both intial construction and life cycle are calculated. The cost of a seismically isolated building is recognized as higher than that of a conventional building,which spoils the mind of implementation of the isolation technology. To evaluate the cost of a seismically isolated building properly,it is necessary to account for the life cycle cost other than initial cost taking maintenance cost and repain cost in case of great earthquakes into consideration.

As the results,the seismic risk reduces to half by ground condition.Though initial investment becomes high so that the strength of earthquake resistant construction goes up,the life cycle costs and the seismic risk become small. If each of the earthquake resistant A,the earthquake resistant B,and the base isolation structure are compared,the seismic risk of the base isolation structure is set to zero,and excels as the earthquake resistant construction. As a quantitative evaluation method,SRM method based on the probabilistic theory is an effective one. Then,the eighth floor steel structure with the base isolation system is applied to obtain the time history responses in comparison of those by the different input wave motions which one the observationary 2003 Tokachi Oki Earthquake has 3.7Hz predominant frequency,and another the simulated earthquake at Nankai offshore has 0.9 Hz one. The base isolation building is able to reduce a strong motion because of the long time period shake,and is effective to the short period large earthquake motion.

2. DEFINITION OF SEISMIC RISK

An expected loss is defined by the product of the loss occurrence probability and the size of loss. ***R***(expected loss value) is written

$$\text{Risk}(\boldsymbol{R})=\text{loss occurrence probability}(\boldsymbol{P}) \times \text{size of loss}(\boldsymbol{C}) \quad \cdots\cdots (1)$$

in which ***R*** is an average value. If both ***P*** and ***C*** are large,risk gets large,contrary to this gets small.

$\sum \boldsymbol{Ri}$(the total of loss risk) corresponded to each of damage form are written

$$\sum \mathbf{Ri}=\sum \mathbf{Pi}\times \mathbf{Ci} \quad \cdots\cdots (2)$$

Risk management is generally composed of three steps

(1) risk discrimination and analysis to evaluate a size of loss and a loss occurrence probability
(2) study of plan to reduce the risk and decision of plan to risk retention or transfer or evasion
(3) practice of a plan

A risk management is a crisis management to control with minimum loss in advance. Both the precautionary measures to decrease the loss occurrence probability and the reduction to decrease the size of loss are available for risk mitigation.

The ground improvement or the structural strengthening are available for the precautionary measure. The stabilized procurement of the emergency materials or the expansion of the fire prevention devices are available for the reduction measure. Investigating from the distribution domain location of the loss occurrence probability(***X*** axis) and the loss(***Y*** axis) shown in Fig.1, the risk is retained regardless to the size of the occurrence probability at the retention domain,and measures such as a compensation or an insurance are taken at the transfer domain,but,in principle measures are given up at the risk evasion. The loss occurrence probability ***P*** is estimated by taking into consideration of damage form such as light or heavy broken. The size of loss ***C*** is estimated from the damages of the structures or the equipment.

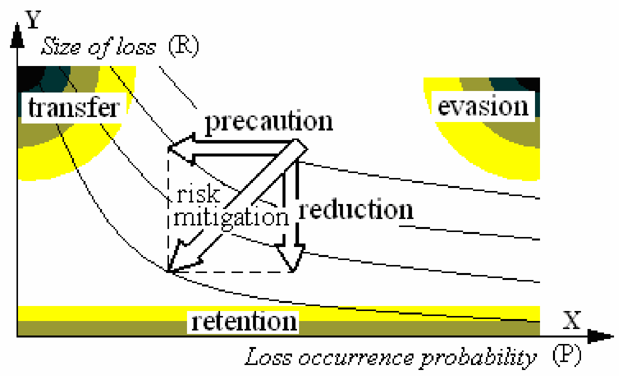


Fig.1 Concept of the risk

3. METHOD AND ANALYTICAL PROCEDURE OF SRM

A pocess of the risk management by flow chart is shown in Fig.2.

3.1. Event tree

An event tree is used to analyze the damage form,making clear the occurrence probability and the size of loss and,obtaining the information on an objective structure. The event tree of the structure about the max. acceleration 300gal is shown in Fig.3 as a typical example. ***R*** becomes smaller by taking measures such as the strengthen a stiffness of ground or structures.

3.2. Fragility curve

A fragility curve which indicates the loss occurrence probability corresponding to a change of the max.acceleration is shown in Fig.4. A necessary probable value at the event tree is obtained by the fragility curve. The analytical method,the statistical one and the experiential one are available to obtain the fragility curve.

3.3. Seismic loss function

The seismic loss function shows the relationship between the expected loss value and the max.acceleration in Fig.5 from which each of the expected loss value can be read.

3.4. Seismic hazard curve

Infoamation of a seismic danger extent in which is represented as a seismic hazard curve is obtained by such past seismic data as geological structures,active fault data. As the seismic hazard curve,an annual excess occurrence probability is as shown in Fig.6.

The annual seismic risk is the product of the seismic loss function and hazard curve.

3.5. Analytical condition of SRM

An analytical condition is shown in Table1. A structural form is the earthquake resistant A(present standard),the earthquake resistant B(increase of 20% about power proof and rigidity) and the base isolation structure.

4. RESULTS OF SRM

4.1. Analytical result

As an example of analytical results,the effect of the aseismatic structural difference is shown in Fig.7(a)(b) in which the initial construction costs increase in alphabetical order,the aseismatic structure A,the aseismatic structure B and the base isolation structure. On the other hand ,the seismic risk and the life cycle costs decrease.

4.2. SRM conclusion

（1）The initial construction costs increase as the strength of aseismatic structure go up,both the seismic risk and the life cycle costs decrease.

（2）The first class type ground condition reduces to half the seismic risk in comparison with the third class type ground condition.

（3）The seismic risk and the life cycle costs increase as the structural scale from third stories to eighth stories become large.

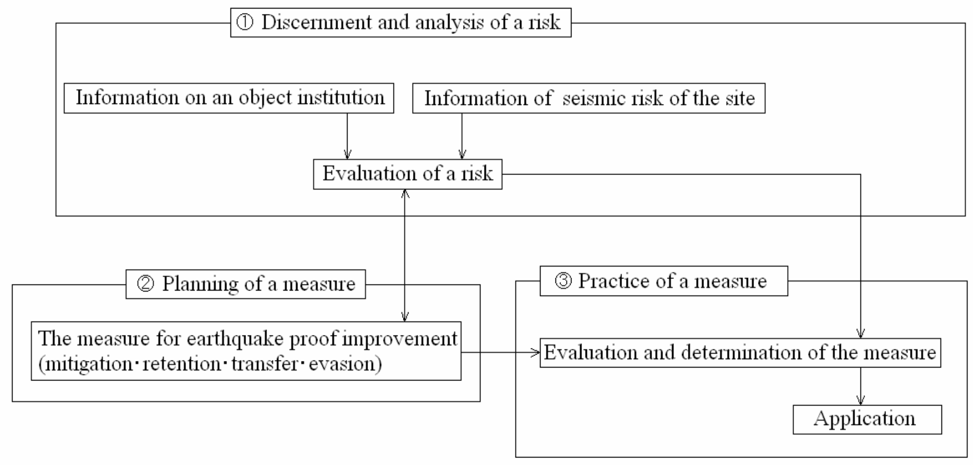


Fig.2 Seismic risk assessment

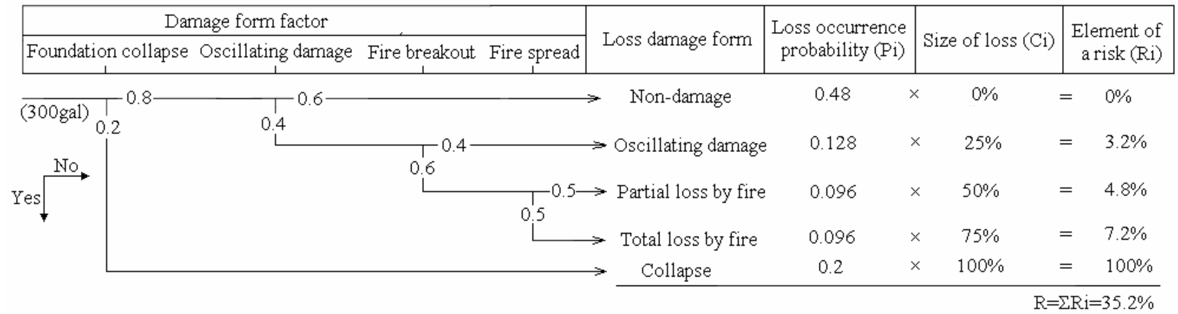


Fig.3 Event tree

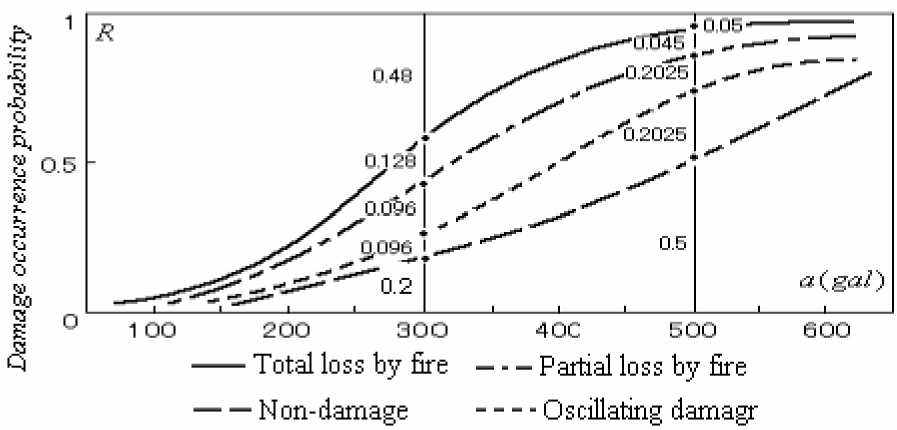


Fig.4 Fragility curve

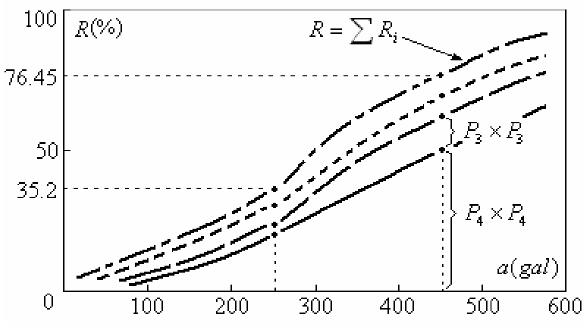


Fig.5 Seismic loss function

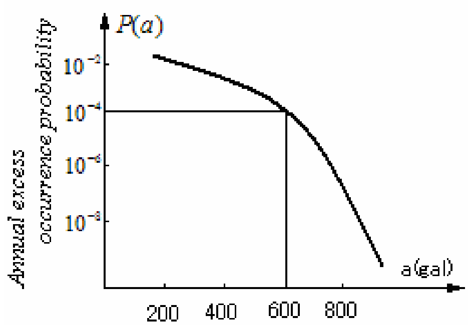


Fig.6 Seismic hazard curve

Table 1 Analytical conditions

Objective region	Kochi Prefecture
Object structure	Structure form：Steel structure Number of stories：Eight stories Standard floor area：600 square meters Total floor area：2400 square meters Structural characteristics：Each of relative displacement is 1.0 Information of proof strength：Standard value
Ground characteristics	Compare hard ground(first class type) with soft ground(third class type)
Scenario two earthquakes	1995 Hanshin Great Earthquake(M=7.2,R=0.6km) and Simulated Nankai Offshore Earthquake(M=8.4,R=100km)

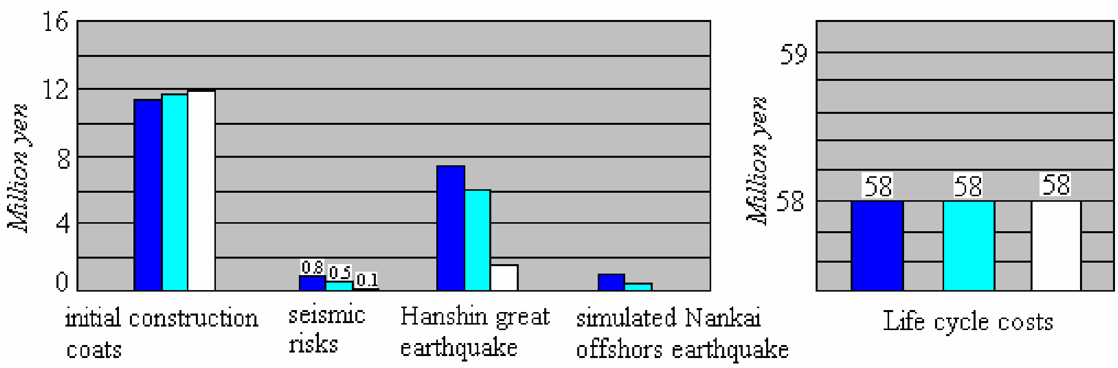


Fig.7 (a) Aseismatic structural form difference on the first class type ground

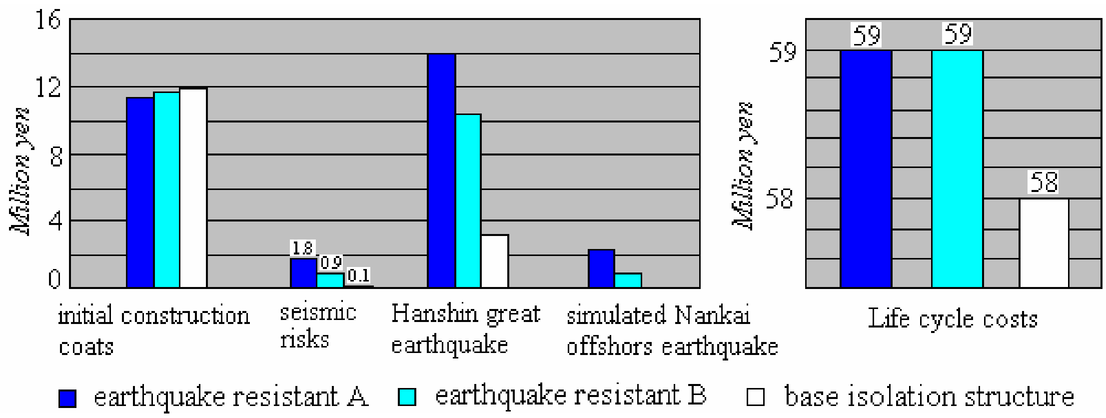


Fig.7 (b) Aseismatic structural form difference on the third class type ground

5. RESPONSE ANALYSES OF BASE ISOLATION

As results of SRM method,the base isolation structure is superior to the aseismatic structure. Then,the eighth floor steel structure with the base isolation system is applied to obtain time history responses in comparison of those by the different input wave motions.

5.1. Dynamic property of eighth story steel frame building

A calculation model with laminated rubber tubes,steel dampers and lead dampers used in isolation devices is shown in Fig.8. Non-linear dynamic characteristics of each story of the structure can be evaluated by a bilinear model are shown in Fig.9 and each restoring characteristics of the base isolation system is shown from Fig.10 to Fig.12.

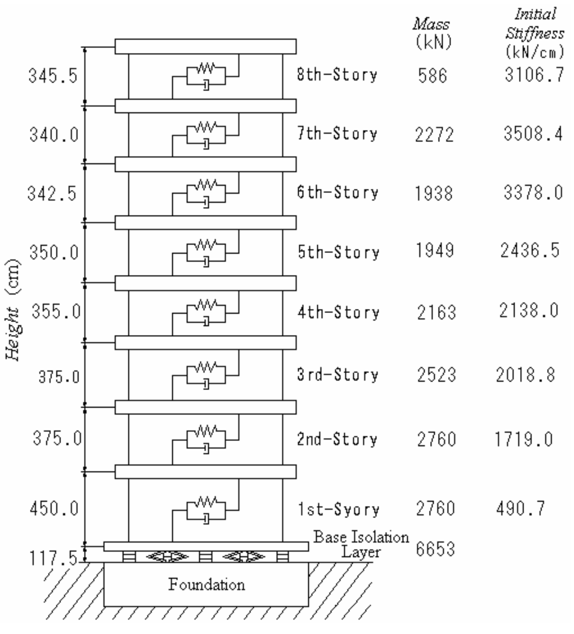
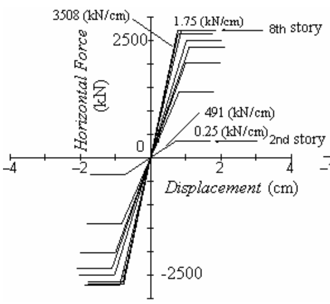


Fig.8 Calculation model



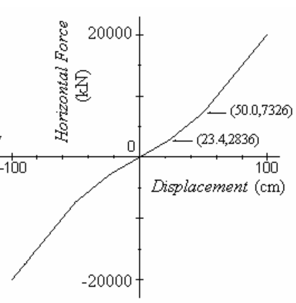
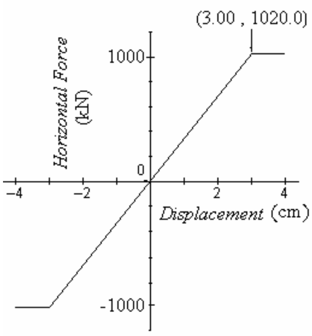


Fig.9 Bi-linear model Fig.10 Laminated rubber



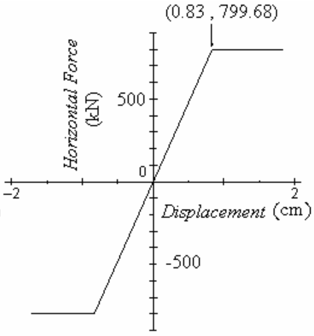


Fig.11 Steel damper Fig.12 Lead damper

5.2. Response analyses by direct integration method

The ground-foundation model is considered as the rigid body when a shear wave velocity is more than 400m/s. The motion equation of an equivalent shearing model considering the equivalent shearing type with the stiffness proportional damping is written

$$[M]\{\ddot{x}(t)\}+[C]\{\dot{x}(t)\}+[K]\{x(t)\}=-[M]\ddot{y}(t) \quad \cdot\cdot(3)$$

$\ddot{y}(t)$ ：input ground acceleration

Two kinds of input wave motions(one is an observational Tokachi offshore Earthquake with the max.973gal and the other is a simulated Nankai Earthquake with the max.420gal) are used at the max.973gal to analyze under the same amplitude condition. An earthquake wave form,a fourier spectrum and a power spectrum of the observed earthquake and the simulated one are shown in Fig.13 and Fig.14. Those predominant frequencies of the observed earthquake and the simulated one are 3.71Hz(predominant period 0.27sec) and 0.88Hz(predominant period 1.14sec) respectively. Comparing to the simulated,the observed earthquake has the long period range and the plural peaks. Hereinafter,the observed earthquake is called as a short period predominant earthquake and the simulated as a long period one.

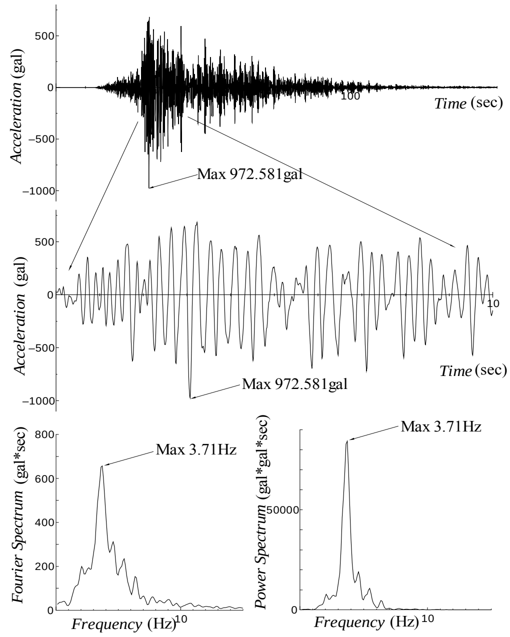


Fig.13 Observation earthquake(short period)

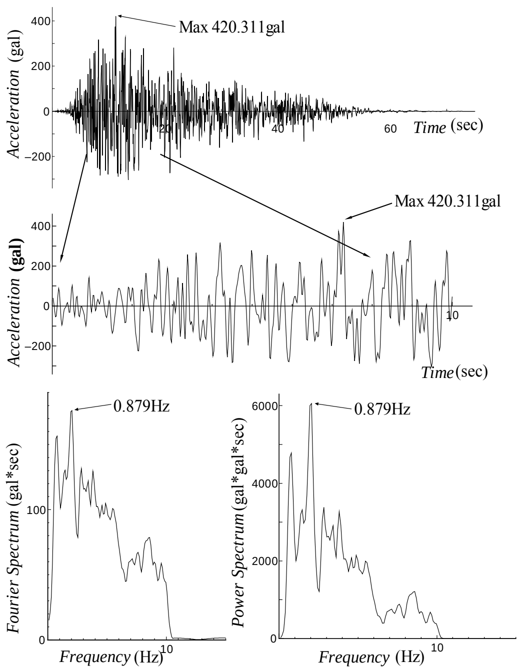


Fig.14 Simulation earthquake(long period)

5.3. Results of response analyses

Predominant periods and mode forms from first floor to fifth one are shown in Fig.15. Shakings of the first and the third mode become large in the upper portion of the building,on the other hand those of the first and the second mode become large in the base isolation layer.

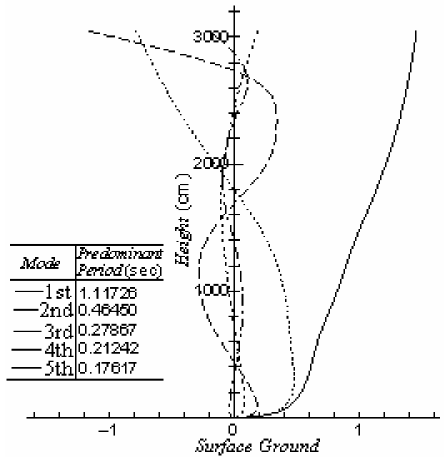


Fig.15 Mode form

Maximum responses of accelerations and shear forces at each floors are shown in Fig.16 and Fig.17. Comparing to the long period,the responses max. acceleration of the short period earthquake is small about 1,000gal differences at each floors.

From Fig.17,top floor responses of shear forces of both the long period earthquake and the short one show larger than under floor those. Comparing to the short period,the responses max. shear force of the long one at the base isolation layer are large about ten times.

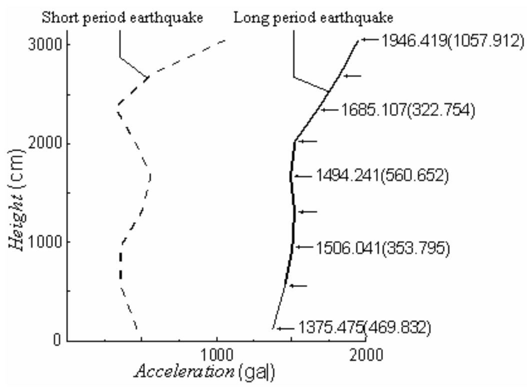


Fig.16 Maximum response of acceleration

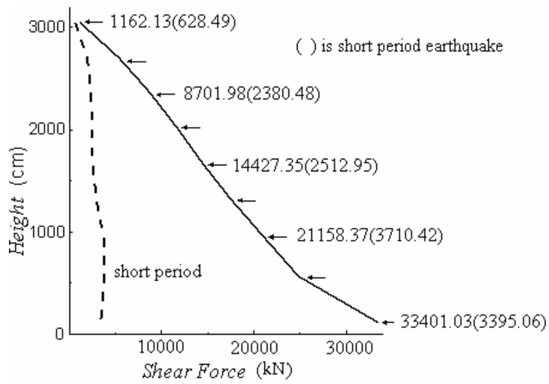
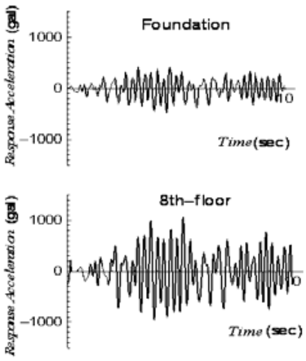


Fig.17 Maximum response of shear force

As a typical example of time history responses, response absolute acceleration of both the base isolation layer and the eighth floor are shown in Fig.18(by the short period earthquake) and Fig.19(by the long one). Similarly,the responses relative displacement are shown in Fig.20(short period) and Fig.21(long period).



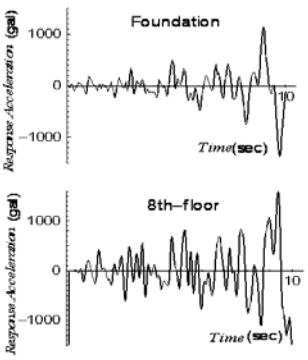
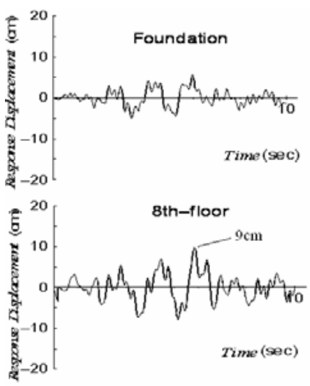


Fig.18 Response acceleration (short period earthquake)

Fig.19 Response acceleration (long period earthquake)

From Fig.18 and Fig.19,at the short period earthquake from three to five seconds the response acceleration becomes large,on the other hand at the long period one from eight to ten seconds that becomes large extremely.



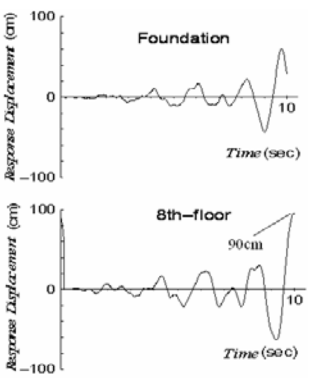


Fig.20 Response displacement (short period earthquake)

Fig.21 Response displacement (long period earthquake)

From Fig.20 and Fig.21,comparing to the response displacement at the short period earthquake,the response displacement wave form between the base isolation layer and the eighth floor at the long period earthquake become large as the time proceeds and become about ten times.

6. CONCLUDING REMARKS

（1）Results of the comparison the building with the earthquake resistance in conformity to the present code,that with the increase of 20% stiffness and that with the isolation using laminated rubber bearings show that the seismic risk of the base isolated building is set to zero,and excels as the earthquake resistant construction.

（2）Results of the time-history response analyses done to obtain the dynamic properties of two kinds of input wave motions(one has the long period and the other short one) show that the base isolation system prolongs the natural period of the building and decreases the earthquake force by the installation of base isolation devices between the foundation and the building.

（3）On the contrary ,because of the swaying slowly,the base isolated building resonates when the long period predominant earthquake occurs or it is built in the soft ground.

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